How many r-processes exist?*

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Abundances of low-metallicity stars offer a unique opportunity to understand the contribution and conditions of the different processes that synthesize heavy elements. Many old, metal-poor stars show a robust abundance pattern for elements heavier than Ba, and a less robust pattern between Sr and Ag. In our recent paper [1], we show that two nucleosynthesis processes are sufficient to explain the stellar abundances at low metallicity, and we carry out a site independent approach to separate the contribution from these two processes or components to the total observationally derived abundances. Our approach provides a method to determine the contribution of each process to the production of elements such as Sr, Zr, Ba, and Eu. Moreover, we use the deduced abundance pattern of one of the nucleosynthesis components to constrain the astrophysical conditions of neutrino-driven winds from core-collapse supernovae.

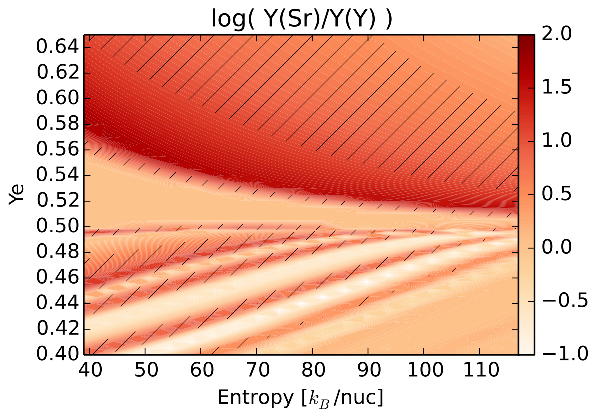

Figure 1: Ratios of abundances for Sr and Y. In the hatched regions the ratios agree with observations, taking into account uncertainties and errors.

Neutrino-driven winds occur after a successful core- collapse supernova explosion, when neutrinos deposit their energy in the outer layers of the neutron stars, and this layer gets ejected (see [2] for a recent review). Although neutrino-driven winds were thought to be the site for the r-process [3], recent hydrodynamic simulations have shown that the required extreme conditions are not reached. It is still possible that the winds have the conditions necessary to produce the lighter heavy elements from Sr to Ag [4]. We have explored which astrophysical conditions are capable of reproducing the observed abundances from Sr to Ag. In order to account for the uncertainty in the wind parameters (entropy, expansion time scale, and electron fraction), we systematically varied them within their expected uncertainty.

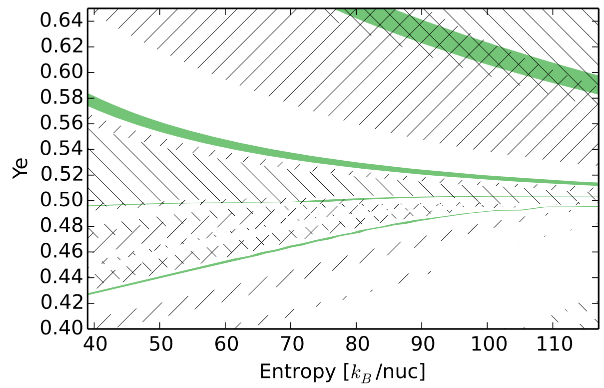

Figure 2: This figure shows the wind parameter space and the regions where the ratios Sr/Y (//), Sr/Zr (\\), and Sr/Ag (green) agree with observations. The three ratios overlap mainly for proton-rich conditions.

Our result are presented in Figs. 1–2. Proton-rich conditions ($Y_e > 0.5$) favor the production of Sr, Y, Zr, and Ag following the observed ratios. If only the observation of Sr, Y, and Zr need to be reproduced, then there are also possible parameter combinations in neutron-rich conditions. Further investigations of the wind and the nuclear reactions involved combined with observations will give rise to new insights on the origin of lighter heavy elements.

References

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* Work supported by Helmholtz-Nachwuchsgruppe VH-NG-825.

DOI:10.15120/GR-2015-1-MU-THEORY-09